FILLING WITH UNCLASSIFIED TAILING IN MODIFIED CUT-AND-FILL STOPES, DAYROCK MINE, WALLACE, IDAHO

BY PETER H. TOEPFER

* * * * * * * * * **Information Circular 7649**

UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary
BUREAU OF MINES
J. J. Forbes, Director

Work on manuscript completed **January** 1952. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is made: "Reprinted from Bureau of Mines Information Circular 7649."

October 1952

FILLING WITH UNCLASSIFIED TAILING IN MODIFIED CUT-AND-FILL STOPES, DAYROCK MINE, WALLACE, IDAHO

by

Peter H. Toepfer[1]

CONTENTS

Page

Summary.. 1
Introduction.................................... 2
Acknowledgments................................. 3
History... 3
Location and mining conditions.................. 4
Stoping methods................................. 4
    Conventional cut-and-fill stoping........... 5
    Dayrock cut-and-tailing fill stoping........ 5
    Tailing preparation and handling............ 6
    Cycle of operations......................... 6
Advantages of Dayrock practice.................. 6
Disadvantages of Dayrock practice............... 9
Methods for control of hydrostatic pressure..... 10
    Method of control using classified sands (former practice)........ 10
Disadvantages of former practice................ 10
    Method of control using unclassified sands (Dayrock practice)..... 10
Characteristics of tailing...................... 11
Underground conditions.......................... 11
Equipment for preparation and emplacement of mill tailing. 12
    Agitator tank............................... 12
Delivery system................................. 13
Filling costs................................... 14

ILLUSTRATIONS

Fig. — Follows page

1. (a) Conventional cut-and-waste fill stoping, as formerly applied in Dayrock mine........... 2
   (b) Dayrock cut-and-tailings fill stoping, showing flexibility of present system.............. 2
2. Agitator tank, Dayrock mine, Shoshone County, Idaho.. 12

---

[1] Mining engineer, Bureau of Mines, Mining Division, Region II.

Information Circular 7649

SUMMARY

Hydraulically emplaced, classified mill sands long have been used for stope fill. Entrained water drains rapidly from this type of fill through openings between the sand grains. Slimes are removed to facilitate drainage of the water, thereby lowering dangerous hydrostatic pressures in the fill.

Use of unclassified mill tailing as practiced at the Dayrock mine is a recent development and represents a fundamentally different approach to the problems of inhibiting the development of hydrostatic pressures within the stope fill. At the Dayrock mine, mill tailing is used to form a densely packed fill of sand and slime particles relatively impervious to additional water.

An advantageous modification of conventional cut-and-fill stoping has been developed in using the tailing fill. The cost of filling by conventional methods ranged from $1.21 to $6.01 per ton of ore extracted. The new filling method has lowered the cost to $0.67 per ton. Important advantages of the new practice are summarized below.

1. The new method needs only one raise to mine an ore block, whereas, in the conventional method, two raises were needed for a block of equal size.

2. Lateral stope boundaries can conform to fault offsets between the raises, thus avoiding sharp tuns in following the ore and blasting the waste.

3. With conventional cut-and-fill stoping, ore blocks containing large waste inclusions cannot be mined profitably. The modified method allows any small area of commercial ore to be mined with minimum breaking of surrounding waste. Noncommercial ore within the stope boundaries can be left in waste pillars. (Dayrock production for the past 2 years has come largely from ore blocks that had been bypassed as being noncommercial under conventional cut-and-fill stoping).

4. Mill tailing is a waste material that is easily and safely handled; moreover, it is produced at approximately the same rate at which filling material is required.

5. The tailing pond need not be as large, and the danger of wash-outs are reduced accordingly.

6. The fluid tailing is delivered through a pipe system independent of the haulage system and does not interfere with ore and service movements.

7. Filling is placed within 2 feet of the back, providing good support for the stope walls and considerably reducing wall-rock dilution.

8. The fluid-tailing fill is leveled naturally and provides a good working and scraping floor within a short time. Broken ore is recovered completely in the scraper operations by removing a few inches of the top of the fill.

9. The fluid tailing produces no dust; on the other hand, moisture from the fill reduces the dust generated in handling the borken ore.

10. The filled stopes do not provide dead-air spaces. Wood buried in the stopes resists decay.

11. Pillars over the drifts can be removed without great difficulty or danger, as the old tailing fill usually stands well, even when undermined. It is possible that shaft pillars can be mined safely if the openings are properly filled with tailings.

12. The fill retains about 10 percent moisture, which penetrates the mine timbers and reduces possibilities of fire.

Disadvantages resulting from the tailing-fill practice at the Dayrock mine are enumerated below.

1. Stope faces are not on the line of air circulation and therefore may require additional ventilation.

2. Development waste usually must be hauled outside the mine.

3. Water drained from the fluid filling must be pumped back to the surface.

4. Excess water from the fill runs down ore chutes, making the broken ore sticky and hard to handle.

5. Some slimes escape during the pour and some fine ore is washed from the ore chutes, requiring the ditches and traps on the lower levels to be cleane periodically.

6. In scraping the surface of the fill, there is some dilution of the bork ore; also there is dilution from the adjoining filled stopes.

INTRODUCTION

A modification of the conventional cut-and-fill stoping made possible by the use of hydraulically emplaced flotation-mill tailing for stope filling is being practiced successfully at the Dayrock mine of Day Mines, Inc., Wallace, Idaho. It is particularly interesting that a large part of this mines's production during the past 2 years has come from ore blocks that had been developed earlier but, because of interspersed areas of submarginal ore, could not be mined profitably by ordinary cut-and-fill stoping. With the present method, these blocks, which otherwise would have been abandoned, are being mined. (Figs. 1a and 1b.)

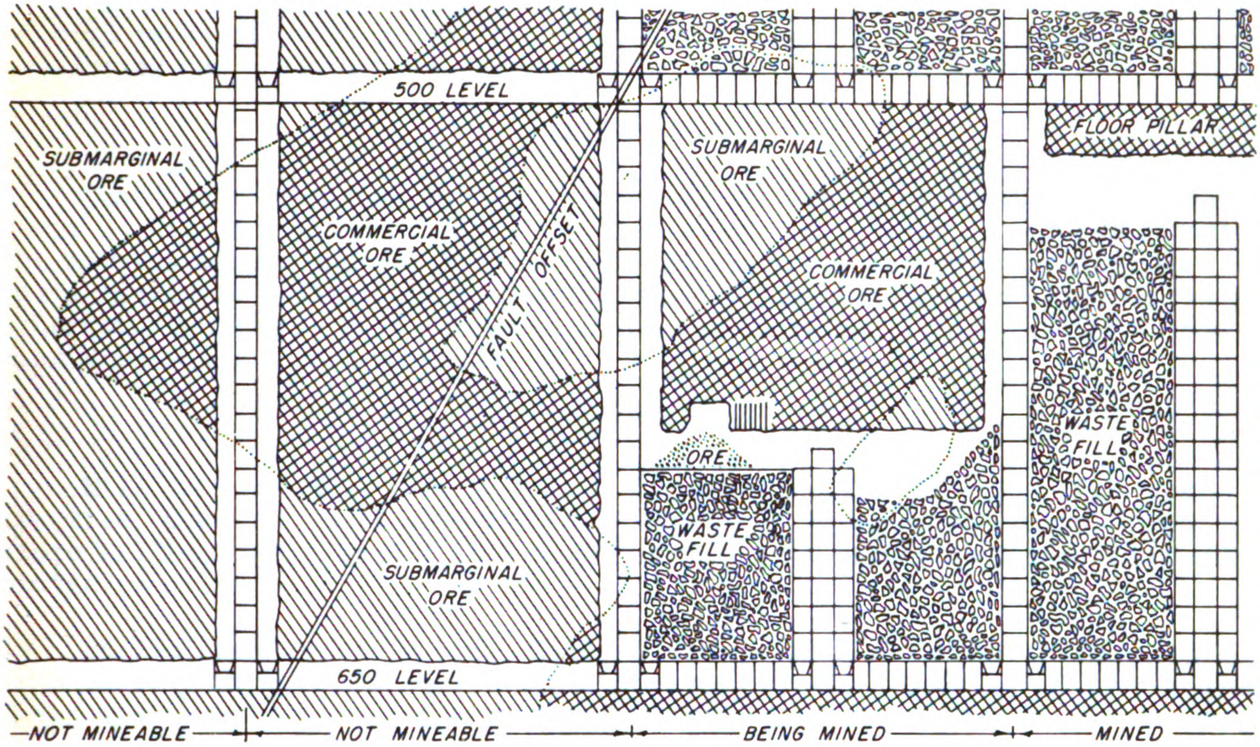

Figure 1a. - Conventional cut-and-waste fill stoping, as formerly applied in Dayrock mine.

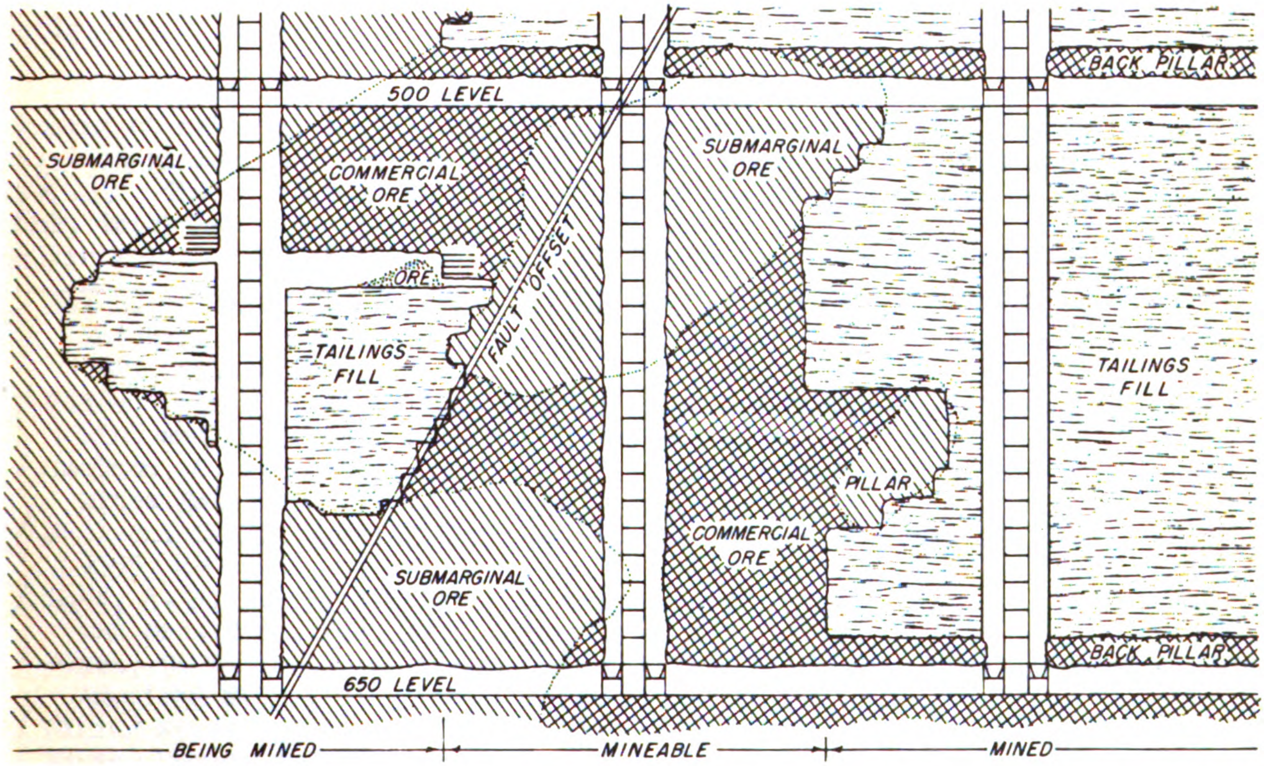

Figure 1b. - Dayrock cut-and-tailings fill stoping, showing flexibility of present system.

In the interest of conservation and effective utilization of our national mineral resources, the progressive attitude of the Day Mines organization in developing and successfully operating this method is commendable.

ACKNOWLEDGMENTS

Complete cooperation in the preparation of this paper has been given by Henry L. Day, president of Day Mines, Inc., and the members of his organization who have developed and are carrying out the stoping. Acknowledgment is due particularly to Rollin Farmin, general mines superintendent, and also to the other staff members, R. J. Horsman, chief engineer; Carville Sparks, general mine foreman; and Fred Torkelson, mine foreman.

HISTORY

Mill tailings long have been used for stope filling.2/3/4/5/ The usual practice, however, is to classify the tailing and use only the coarse sands for stope filling, which give a free-draining fill that minimizes danger from hydrostatic pressures.

In 1932 the Homestake mine, Lead, S. Dak., began sluicing finely ground sand tailing to fill old square-set stopes in order to mine the pillars between those stopes and to prevent surface subsistance.6/

The operators at the Sliger mine, Georgetown, Eldorado County, Calif., studied the Homestake-mill sand-fill method and concluded that the unclassified Sliger flotation-mill tailing would be satisfactory fill material. Since 1940, such material has been used successfully in the regular cut-and-fill stoping cycle.7/

Success at the Sliger mine led to adoption of tailing fill in cut-and-fill stoping at other mines,8/9/ among them the Brunswick, operated by the Idaho-Maryland Mining Co. at Grass Valley, Calif., where tailing fill was adopted in 1946.10/ There, flotation-mill tailing was pumped directly to an agitator tank, thickened, and introduced into the stopes in batches from the tank. Rollin Farmin, assisted by Carville E. Sparks, is credited with this pioneer work.

2/ Reichert, George L., Filling Stopes with Mill Tailings at Minas de Matahambre, in Pinar del Rio, Cuba; Eng. Min. Jour., vol. 127, March 1929, pp. 348-352.

3/ Eaton, Lucien, Sand Filling Through Pipes and Boreholes; Trans. Am. Inst. Min. and Met. Eng., vol. 102, 1932, pp. 33-41.

4/ Jackson, C. F., and Gardner, E. C., Stoping Methods and Costs; Bureau of Mines Bull. 390, 1937, 296 pp.

5/ Jackson, C. F., Waste Filling of Stopes; Bureau of Mines Inf. Circ. 6816, 1935, 24 pp.

6/ Ross, A. J. M., Sand-Filling at the Homestake Mine; Am. Inst. Min. Eng. and Met. Tech. Pub. 1075, 1939, 15 pp.

7/ Plumb, C. W., Filling Mine Stopes with Mill Tailings; Pres. at meeting, American Mining Congress, San Francisco, Calif., 1941.

8/ Mining World, Tennessee Schuylkill; Vol. 8, August 1944, pp. 11-15.

9/ Mining World, Central Eureka Cuts Mining Costs; Vol. 13, February 1951.

10/ Krebs, Richard, and O'Donnell, J. C., Sand-Slime Stope Filling Proves Satisfactory; Eng. Min. Jour., vol. 150, January 1949, pp. 54-60.

The present stoping operations at Dayrock were introduced in June 1949[11/][12/] as developments from the Brunswick mine.

LOCATION AND MINING CONDITIONS

The Dayrock mine is 3-1/2 miles north of Wallace on Ninemile Creek Road in the Coeur d'Alene mining district, Shoshone County, Idaho.

The major veins are the Dayrock and the Ohio, with stoping mainly on the latter. Both are typical sideritic, galena-bearing veins of the Coeur d'Alene district, occurring in the St. Regis quartzite of the Belt (Algonkian) series. The Dayrock and Ohio veins are roughly parallel, nearly vertical, and about 250 feet apart. Locally, dips are erratic, in places being as flat as 30°. The Ohio vein averages 2.9 feet in width in the stopes but is as wide as 8 feet at spurs and swells. Mineralization is not continuous throughout the vein; workable portions may be only 25 feet long and 25 feet high or may reach a length of 400 feet or more. In the latter instance, numerous submarginal areas must be left as pillars. Cross faults offset the vein as much as 5 feet and complicate the mining.

The only ore mineral is silver-bearing galena; the cut-off assay is 3.7 percent lead. Sphalerite is present, the zinc averaging 0.5 percent in the mill heads; this is not considered enough to make a zinc concentrate. The gangue minerals are bleached quartzite, quartz sericite, and minor amounts of siderite and pyrite.

The Ohio vein is developed for a length of 2,000 feet and to a depth of 700 feet below the Ohio adit level. The ore is hoisted 100 feet above the Ohio adit and trammed to the mill through the Dayrock adit. The ore bodies do not extend far above the upper adit levels, and the stopes do not reach to the surface.

The Dayrock vein is stoped 300 feet below the Ohio adit and is considered worked out above that level. As in the Ohio vein, none of the Dayrock stopes extend to the surface.

The mine is quite dry. Since the stopes do not open to the surface, seasonal variations in surface water do not greatly affect the flow in the mine. The fractured quartzite country rock drains easily to the sump. The normal amount of water pumped is estimated to be 9,000 gallons daily, and 50 percent of this water is estimated to originate in the tailing used for stope filling. Seasonal variations in ground water may increase the normal amount of water pumped by 50 percent.

STOPING METHODS

Many factors were considered in choosing the stoping method. The veins are relatively narrow, though of varying width. The dip is very erratic and may

---

[11/] Mining World, Sand Filling Pays Off at Dayrock: Vol. 11, October 1949.

[12/] Farmin, Rollin, and Sparks, Carvill E., Sand-Fill Method at Dayrock Resulted in These 12 Benefits; Eng. Min. Jour., vol. 152, September 1951, pp. 92-97 reverse itself. Stope backs stand unsupported during mining, except in wide sections where posts and headboards are needed. The wall rocks are weak and tend to slab, requiring close filling after stoping to prevent dilution by wall rock. Lean portions of the veins must be left as pillars or blasted as waste. The erratic mineralization requires complete development in advance of stoping. Cut-and-fill stoping appeared most suitable under these conditions and was adopted at Dayrock.

Conventional Cut-and-Fill Stoping

Figure 1a shows the conventional, horizontal cut-and-fill stoping previously used at the Dayrock mine. Raises 100 feet apart were driven from level to level, completely developing the ore in blocks. A manway with ore chutes was driven upward midway between the end raises. The ore was mined in 7-foot horizontal slices outward from this manway. After each horizontal cut was taken, waste rock was dumped down the adjoining chute and leveled with a slusher. After a plank floor was laid on this waste fill, vertical holes were drilled up into the vein, and the next horizontal slice was blasted in a series of rounds. The broken ore was scraped to the manway ore chute, the plank floor taken up, and waste fill again dumped down the raise chute. As each ore block was divided into two stopes by the manway raise in the center, drilling and blasting were under way on one side of the manway shile the floor was taken up, the manway was raised, the waste fill was leveled, and the floor was laid on the other side. Lean areas in the vein were blasted as waste fill, since they could not be left as pillars. A crown pillar was left below the upper level; the grade of the ore seldom warrented mining this pillar.

Dayrock Cut-and-Tailing Fill Stoping

Figure 1b shows the modification of cut-and-fill stoping made possible by using mill tailing for filling, the practice now used at the Dayrock mine. Raises 100 feet apart are driven from level to level, completely developing the ore blocks. In the upper part of the mines, the interval between levels is 100 feet, but the two lower levels are 150 feet apart, an interval that seems to be satisfactory for this method. In the previous method, the ore-block boundaries conformed to the raises, whereas, in the present method the ore-block boundaries are midway between the raises. Thus, instead of requiring a new manway raise, each ore block is worked from the development raise already driven, dividing the block into two 50-foot stopes. A back pillar is left above the lower level so that the first pour of thickened tailing may be made without excessive preparation to prevent leakage of the fluid pulp. The ore is mine upward in a series of 7-foot horizontal cuts. When each horizontal cut is completed, the broken ore is scraped out, and a vertical dam of 3- by 12-inch planks is built between the open stope and the raise chute. This dam fits closely between the stope walls and is spiked to stulls. A number of 1-inch holes are bored through the planks of the dam to permit most of the water to escape by decantation while the fill is being poured. Old burlap sacks nailed inside the dam allow the water to seep through but retain solids in the stope. The dam becomes one side of the ore chute, and the fill compacts in place behind it.

Digitized by Google Original from THE OHIO STATE UNIVERSITY

Tailing Preparation and Handling

From the flotation mill, fluid tailing containing about 20 percent solids is pumped directly to a settler-agitator tank. Excess water overflows, carrying out some of the finest slimes. Pulping is topped after a tankful of solids has accumulated, and agitation is begun 1/2 hour before pouring, giving enough time for thorough mixing to a uniform pulp. The tailing, containing 69 percent solids, is allowed to flow by gravity in a pipeline to the stope being filled; it flows from the pip into the stope. The solids settle rapidly, but care must be taken to insure that the surface water drains off through the dam and does not stand in ponds. In wider stopes several pourings from the agitator tank are necessary to complete the filling. The fill is carried to within 2 feet of the back. The surface of the fill soon hardens, and the next shift can drill and blast. A plank floor is not needed on the fill.

Cycle of Operations

Horizontal holes are drilled into the vein in a series of inverted bench rounds, and the ore is blasted down into the fill. Most of the broken ore is scraped out after each round is blasted. When the horizontal cut is completed, broken ore remaining on the fill is scraped to the raise chute. The tailing provides a firm horizontal surface, but several inches is purposely scraped from the top to be sure that no ore is lost. The method permits regular working cycles because ore is drilled and blasted in one stope while the dam is built and the stope is filled in the other. Submarginal portions of the vein generally can be left as pillars, though, if desired, they may be blasted as waste to form part of the stope filling. Mining proceeds upward to the next level, where no crown pillar need be left, as the tailing fill becomes the drift floor. If a retreat sequence of stoping is followed, it is possible to recover the back pillars left above the levels, because experience has shown that the tailing fill stands very well, even when undercut. In wide, vertical protions of the vein, however, it is considered advisable to lay a timber mat on top of the back pillar before filling begins. The mat then can be caught up when the pillar is recovered later, preventing caving of the overlying fill.

The Dayrock mill handles an average of 200 tons daily. This ore is produced by an underground crew of 65 men; 3.385 tons per man shift is produced daily.

ADVANTAGES OF DAYROCK PRACTICE

The Dayrock modification of cut-and-fill stoping has many important advantages.

Only one raise is needed for each ore block, whereas previously an additional manway raise had to be driven for stoping an ore block of equal size. In these narrow veins the raises must be driven wider than the stopes, which results in dilution. Fewer raises decrease the tonnage of diluted ore produced.

Where faulting offsets the vein between raises, the offset can become the stope boundary. Formerly, the stope had to angle sharply to follow the ore, complicating the slushing and diluting the ore.

In the conventional cut-and-fill method, lean parts of the vein usually had to be broken to maintain access across the stope back. In the Dayrock modification, such lean areas are left as pillars. If the waste is near an ore-block boundary, the length of the horizontal cut merely is shortened. If the waste occurs centrally at the raise, a pillar is left, and any ore remaining within the block boundary on the far side of the pillar is mined by extending the stope length of the adjoining ore block. Waste that must be blasted down can be used as part of the fill.

Mill tailing is an easily and inexpensively handled waste material, which is produced at not less than the rate at which filling is required. Development waste may be considered to cost nothing delivered to the stope, since otherwise it would have to be hauled out of the mine. Even so, development waste may be on hand at times when no stope is ready to receive it. Development generally cannot supply all of the waste necessary; and, in lieu of tailing, most of the waste at the Dayrock mine would have to be mined from a special waste stope or from the surface. The cost of mining waste, plus a proportional charge for haulage, plus the cost of waste pockets and chutes must necessarily be included in the total cost of waste-rock fill. Using flotation-mill tailing, the first cost consists of the price of the sand pump at the mill, the pipe system, the agitator tank, and installation. Operating and maintenance costs are nominal. The man operating the agitator tank replaces the man who otherwise would be maintaining the tailing pond. It is to be noted that handling rock waste entails hazards largely absent when mill tailing is used.

When the waste fill is taken directly from the mill, a large tailing pond is not necessary. A settling pond is needed but requires less attention. A decrease in the size of the tailing pond reduces the danger of wash-outs.

The fluid transfer of tailing fill through a pipeline avoids interference with ore haulage and mine supply. Waste haulage formerly was given precedence over ore haulage because waste had to be supplied rapidly while the stopes were being filled. The waste fill could be leveled in the stopes faster than it could be trammed, sometimes leaving the miners idle. Transportation of stope fill in pipelines greatly reduces the load on the haulage system. With the conventional waste-fill practice, two shifts were required to maintain the daily mill requirements. Now, only one stoping shift per day is necessary for the same tonnage. Reduction to one shift with consequent lowering of supervision costs resulted largely from simplified haulage.

The present practice permits filling the stope to within 2 feet of the back, as the fill can be as high as the end of the discharge pipe because the fluid tailing levels approximately to that height. Horizontal breast rounds are drilled, and no one needs to enter the stope after filling. The previous practice was to fill to about 7 feet from the back, because enough headroom had to be left for the miners to lay the floor, drill vertical holes into the vein, and load explosives. Closer filling considerably reduces dilution from the walls.

Leveling of the coarse waste fill was difficult. After the fill was spread with the slusher, hand shoveling was necessary to obtain an even surface upon which to lay the plank flooring. With fluid filling, leveling takes place naturally without the hand shoveling. After settling and draining, the tailing fill provides a fine, natural scraping floor, which eliminates the need for laying planks, lifting them, and setting them aside for filling; moreover, the cost of the planks, which last only a short time in the stopes, is saved. Some of the fine ore always was lost through the flooring when planks were used over coarse waste fill. In the present practice, none of the ore is lost, as several inches of the top of the fill is taken in scraping the broken ore to the chute. The light scraper does not bite deeply into the packed tailing fill.

The dust hazard has been reduced greatly by use of the tailing fill. Formerly, waste rock dumped down raise chutes produced siliceous dust in harmful quantities. Filling with fluid tailings produces none. Much dust also was raised in scraping the ore from the plank flooring, and water sprayed on the ore pile would not penetrate enough to wet the interior of the pile. Now, little dust is raised in handling broken ore because the ore blasted down absorbs water by capillary action from the top of the fill, the fill surface having been further wetted by the drilling water.

General mine ventilation has improved since introduction of this method. Reduction in the number of raises has reduced dispersion of the air currents. The filled stopes do not provide dead-air spaces. Timber buried in the filled stopes resists decomposition and formation of timber gas.

More complete ore extraction is possible by this method. Previously, a floor pillar was left below the upper level, since before this pillar could be taken out much additional timbering had to be done on that level to prevent the collapse of the waste filling above. The vein seldom was high grade enough to bear this cost. In the present method, the crown pillar is not left, because the tailing fill provides a good floor for the level above the stope. In retreat mining, the pillar over the drift can be taken out when the stope from below reaches that level. Old tailing fill, except where the vein is wide and vertical, stands very well, even when undermined. The staff of Day Mines, Inc., believes that tailing-filled stopes generally equal pillars in strength and that ore pillars ordinarily left to protect main shafts can be mined without endangering the shafts if the openings are filled with the densely packed tailing.

The tailing fill retains a moisture content of about 10 percent. Moisture penetrates mine timbers to the extent that they will not catch fire readily and thus largely removes a fire hazard present in all heavily timbered mines.

In mines where sulfide-ore fires are apt to occur, a moist, densely packed fill would prevent such fires from developing in the stopes. Furthermore, fires already begun in other mines have been effectively blocked by filling with tailing around the fire areas.

With consistent use of tailing fill in a mine, it is believed that development of rock bursts can be delayed, particularly those caused by the collapse of rock pillars. Increase of pressure on rock pillars causes, first, gradual spalling and, finally, complete collapse, resulting in a rock burst. If mill tailing is used for support of wall rocks instead of rock pillars, any increase of pressure is opposed by an increase in the compressive strength of the fill; also, stresses are distributed over a greater surface than would be the case with pillar supports. Rock bursts and ground movement, therefore, might not occur as soon as normally would be experienced.

DISADVANTAGES OF DAYROCK PRACTICE

Conventional cut-and-fill stoping provides adequate air circulation throughout the stopes. In the present Dayrock method, however, the air goes directly up the raise, and the stope faces are not on the line of circulation. Were the mine to be operated on a two-shift basis, blasting fumes probably would be found in the stopes during the second shift. Inasmuch as introduction of the new method permitted a one-shift operation, however, enough time elapses between working shifts for the fumes to be removed. If better stope ventilation is needed, ducts may be installed at the ends of the stopes by carrying up sheet-metal pipes or wooden boxes from the level below, extending them before each pour.

Development waste usually must be hauled outside of the mine and dumped, though under favorable conditions it can be used as stope fill upon which the fluid-tailing fill is poured. In the previous practice, waste always could be used for stope fill.

The water draining from the thickened tailing after placement in the stope, must be pumped to the surface. The fluid tailing carries 30 to 32 percent water, of which about 10 percent is retained in the fill. At the Dayrock mine about 4,500 gallons of water drains from the filling daily and must be pumped to a maximum height of 700 feet. The cost of pumping will increase as the mine reaches greater depths.

Excess water from filling runs down the ore chutes, wetting broken ore and making it harder to handle. If the chutes are emptied before the pour, the ore next dropped down may break the bottom-chute timbering.

A small amount of slime escapes with the water decanted from the fill, while the water running down the ore chutes washes some fines, resulting in the necessity for periodic cleaning of settling traps along the ditches and at the sump.

Conventional cut-and-fill stopes were bounded on both ends by raises that prevented dilution from adjoining filled stopes. In the present modification, dilution from the adjoining filled stopes is negligible. The old fill stands quite well. It is claimed that tailing fill of this type at Grass Valley, Calif., once stood unsupported for a vertical height of 40 feet. In the Dayrock stopes, the fill needs to stand only the 7-foot height of the horizontal cut plus the 2-foot opening below the back, a total of 9 feet.

Some dilution also occurs when the top of the fill is scraped to a depth of several inches to remove all the broken ore, this layer purposely being taken to recover those particles that are driven into the fill. This previously ground-diluting material passes rapidly through the ball mill and flotation circuit, however.

Precaution must be exercised in using pyritic tailing as stope fill, because each filling may become a fire hazard subject to spontaneous combustion if enough pyrite is present. This is less of a danger with the water-soaked tailing fill than with dry, coarse waste fill. This danger is not imminent at the Dayrock mine, as the tailing carries only a small amount of pyrite.

On the Witwatersrand in South Africa, classified tailing sand from gold cyanidation is used for stope filling. There, the poisonous cyanide is neutralized with potassium permangenate.[14] Cyanide is not used in the Dayrock flotation mill and therefore presents no hazard.

METHODS FOR CONTROL OF HYDROSTATIC PRESSURE

Thorough engineering studies must be made before the Dayrock system of filling can be recommended for other mines; without such studies, adoption of the practice might lead to disaster. Absorption of mine water with consequent possible build-up of great hydrostatic pressures within the tailing fill is a problem that must be examined carefully. Only theoretical consideration can be given, because data on the development of such pressures within the fill are lacking. Much additional experimental work will be required to investigate this problem thoroughly. Two methods for controlling hydrostatic pressure in the fill have been developed.

Method of Control Using Classified Sands (Former Practice)

Hydrostatic pressures are avoided in stopes filled with classified mill sand by rapid drainage of water through the grain interstices. Precautions are taken to remove slimes that might retar drainage of the fill and allow water to accumulate and develop pressure.

In certain instances, mill tailings have been pumped at a continuous rate into old stopes to fill them and prevent surface subsidence, rock bursts, and caving of the hanging walls. Workings so filled must be sealed off by strong bulkheads, as the fluid mass exerts strong hydrostatic pressure. Drainage and relief of hydrostatic pressure can be obtained by opening valves in pipes through the bulkheads to release impounded water.

DISADVANTAGES OF FORMER PRACTICE

During filling, water accumulates above the settled solids, and quiet settling of solids through overlying water does not produce good compaction. After excess water drains away and a stabilized condition is reached, the fill contains a large proportion of small, air-filled voids and shrinkage cracks. Should water again reach the fill, the mass would be easily penetrated and resume its fluid state. For this reason, tailing fill so introduced should always be regarded as a heavy fluid held in place by the bulkheads. If a bulkhead fails, the whole mass would flow into lower workings, endangering workmen and operations and making rehabilitation expensive.

Method of Control Using Unclassified Sands (Dayrock Practice)

The use of hydraulically emplaced mill tailing, as practiced at the Dayrock mine, is a recent development in this country and represents a different approach to the problem of possible development of hydrostatic pressure. No effort is made to classify the mill tailing, although some slimes are lost by decantation during thickening at the agitator tank. The objective is to produce a rigid, impervious fill, in which the slime particles fill the interstices between sand grains, and form a densely packed aggregate, the voids of which are completely filled with water held by capillarity. Further water, in theory, cannot be absorbed without expansion of volume. The fill is poured in successive 7-foot horizontal layers, permitting the solids in the thickened pulp to settle out compactly in swirling water to form a dense aggregate. Excess water is drained off by decantation, the fill retaining only about 10 percent moisture permanently. It is believed that the fill, without freedom to expand, cannot absorb more water. An interval of several days passes between the pouring of each 7-foot layer, and during this period the fill is compacted further by the miners working on it and by the ore blasted. Any contraction cracks that may develop are filled by the next pour. The resultant fill is virtually an impervious mass that does not lend itself to development of hydrostatic pressures.

---

[14] Work cited footnote 3.

CHARACTERISTICS OF THE TAILING

If a tailing should have too high a ratio of sand to slime, the fill would be neither impervious nor free draining. On the otherhand, if the tailing has too low a sand-slime ratio, it does not have the rigidity imparted by the sand grains, and the whole mass may become a heavy, viscous fluid. This particularly can be the case if the slime is composed mainly of such clay minerals as sericite, chlorite, and kaolin. Both screen tests and mineralogical composition must be considered. Tailing containing a high proportion of clay minerals must be classified before being used for fill.

Numerous screen tests of Dayrock tailing made during the past 2 years show wide variations in sizing without apparent adverse effect. Formerly, the tailing averaged 68 percent in the minus-200-mesh size. Milling practice has been improved by the recent adoption of double (flash) grinding, so that now the tailing frequently contains as little as 40 percent in the minus-200-mesh size.

Partial classification occurs during filling of the agitator tank owing to overflow of some of the slimes. Clay minerals tend to overflow more readily than others. A sample taken on July 2, 1951, gave the following results:

	Mill tailing		Stope filling	
	Percent	Cumulative	Percent	Cumulative
+100-mesh.................	17.65	17.65	24.40	24.40
-100-mesh +200-mesh......	37.80	55.45	42.80	67.20
-200-mesh.................	44.55	100.00	32.80	100.00

UNDERGROUND CONDITIONS

The Dayrock mine is relatively dry, and the wall rocks drain well; heavy seepages or localized flows of water into the stopes do not occur. Surface water cannot flow into the workings through the stopes because they do not connect to the surface. The mill tailing is relatively low in clay-like minerals. Under similar conditions, the use of tailing fill in other mines can be confidently recommended.

The Dayrock operators believe that the tailing fill is impervious to the addition of water beyond the 10-percent moisture held by capillarity as long as the fill is confined and cannot expand to accommodate more water. On this assumption, the fill will not absorb enough water to develop hydrostatic pressure and flow as a fluid.

Under certain conditions, it may be found that the inherent imperviousness of the fill will be overcome. For example, it might prove dangerous to use tailing in a mine where there is regular or seasonal seepage of water from stope walls. That water, itself under hydrostatic pressure, might be forced into the fill to develop additional pressure there. Percolation channels might also become established along stope walls. If so, the fill material along those channels might wash out, ultimately providing room for expansion of the fill and absorption of water. Such conditions do not prevail at the Dayrock mine.

Stopes that open to the surface can subject a mine to periodic flows of water from storms and spring run-off. After reaching the main levels, however, mine water presents little danger if confined to regular channels. The water should not be allowed to find its way to the lower levels through hidden courses.

At the Dayrock mine, water may be seen flowing along drifts on top of tailing-filled stopes. None of this water appears to be lost by seepage into the fill. There may be very slow downward percolation through the capillary interstices of the otherwise impervious fill, but this is retarded by the sealing action of slime carried in the ditch. The water is not allowed to flow rapidly enough to wash out fill material or stand in puddles that might establish seepage channels along the stope walls.

EQUIPMENT FOR PREPARATION AND EMPLACEMENT OF MILL TAILING

The mill tailing contains about 20 percent solids and requires only thickening to prepare it for stope fill. The collector and frother have no effect upon use of the tailing for the stope fill. A 3-inch centrifugal pump lifts this material directly to the agitator tank through a 4-inch pipeline. No trouble has been experienced from freezing, although the pipe is exposed to the weather.

Agitator Tank

The agitator (fig. 2) is a wooden tank 14 feet in diameter and 18 feet high. Its size was determined by computing the volume required for accumulating 80 percent of the solids in the tailing during 10 hours of mill operation. This volume permits two pourings daily. The tank acts as a thickener; the fluid tailing entering the tank is directed against a steel plate to reduce turbulence and promote quiet settling of the solids, and the excess water and slime overflow. When a stope is ready for filling and a tankful of solids has accumulated, the operator observes the amount of water above the settled solids and, using a sliding gate, decants enough to adjust the density to the desired 69 percent solids.

About 30-minutes agitation is necessary to thoroughly mix the settled solids. The agitator mechanism is a propellor type, with four 1- by 4-inch flat-steel,

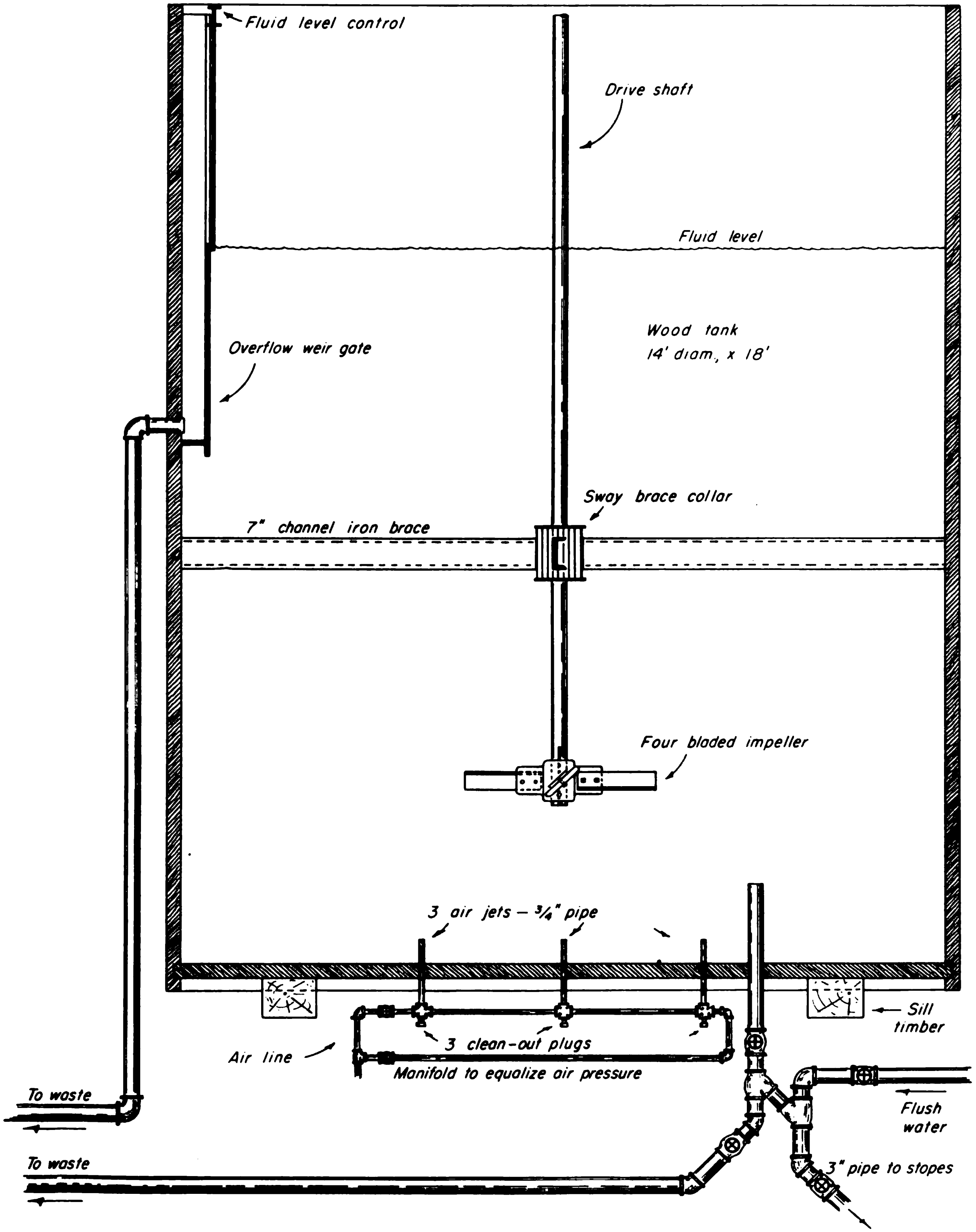

Figure 2. - Agitator tank, Dayrock mine, Shoshone County, Idaho.

horizontal blades, two of which extend 1 foot 6 inches and the other two, 1 foot 9 inches beyond the axis of the vertical drive shaft. The flat bars are inclined 45 to impart circulation to the pulp. The drive shaft is 3-5/16 inches in diameter and is driven at 100 r.p.m. by a 40-hp. electric motor. At the beginning of agitation, compressed air at 100 p.s.i. is introduced through four 3/4-inch jets at the bottom of the tank. This breaks the settled solids enough to permit the mechanism to turn. The motor is reversed every few minutes at the beginning of agitation. No trouble has been experienced in starting the agitator, even after the charge has been allowed to stand as long as 18 hours. Experience has shown, however, that if agitation is interrupted and the solids again settle, the agitator is very difficult to start because of the resulting compaction. A small leak in the air jets will even result in compaction.

DELIVERY SYSTEM

A telephone system provides communication between the agitator tank house and the stope being filled. Before filling is begun, water is flushed through the delivery pipeline until unimpeded flow reaches the stope. The tank operator, then informed, shuts off the flushing water and opens the tank valve, allowing the fluid pulp to flow into the stope by gravity. Agitation is continued during pouring. Air must be kept out of the pipeline during pouring to prevent air locks. After the tank charge is emptied, water is flushed through the delivery line again. The pour is complete in about 35 minutes.

The base of the agitator tank is 40 feet above the level through which the the fluid fill material enters the mine. The minimum hydraulic gradient has not been established, but tailing with 68 to 70 percent solids has been carried successfully 1,500 feet horizontally with a 240-foot head. The delivery pipeline should be on a down grade for its entire length; where low points cannot be avoided, provision must be made for drainage after each pour. Fill material has been introduced up raises with no difficulty other than the necessity of breaking the pipe at the low point and flushing after each pour.

The pulp flows through a 3-inch standard pipeline having flexible, leak-proof couplings. Bends in the pipe are sweeping curves to prevent undue wear and friction. Except for the ordinary plug valve at the base of the agitator tank, no valves or restrictions are placed in the delivery line; otherwise, the pipeline might be plugged. The pulp is delivered to a particular stope by removing lengths of pipe from the main delivery line and replacing them with curved or straight segments, which connect to that stope. The pipeline extends into the raise; the pulp is carried to the center of the stope by a lightweight aluminum pipe hung along the back. The fill settles almost horizontally, and the final flushing water tends to level it further.

Wear in the pipe has been negligible after an estimated flow of 20,000 tons of filling. The slimes apparently cushion the pipe walls from abrasion by the sand grains, and the viscous pulp moves mainly in the interior of the pipe rather than along the walls.

Preparation of the stope for filling has been described as part of the stoping system. Before pouring, cracks found in the floor and walls are plugged with excelsior and sand to prevent water in the filling from seeping behind any slabs of wall rock at the raise and thereby developing hydrostatic pressures, which might break the raise timbers.

FILLING COSTS

The following paragraph and table are taken from a manuscript (Engineering and Mining Journal, September 1951) Rollin Farmin and Carville E. Sparks.[15]

> Cost of filling an average Dayrock stope by each of three methods is given in the following table. For this purpose, the sand is classed as "no cost" material at the mill and the waste as "no cost" when loaded on cars at the development heading; the quarried waste carries the cost of excavation in a development heading run primarily to provide stope filling. (The cost is based on a nominal miner's wage of $12.45 per day, which actually averages $15.86 in payroll expense.)

	Cost of filling per ton of ore extracted	Cost of filling per ton of fill emplaced
Sand-fill stopes	$0.67	$1.23
Waste-fill stopes	1.21	1.81
Quarried waste-fill stopes	6.01	9.02

	Cost of stope chutes and fill lacing
Sand-fill stopes	$ 8.80 per vertical foot
Waste-fill stopes	12.57 per vertical foot

	Installation cost of sand-fill plant
Surface plant (salvaged materials used extensively)	$3,485
Underground trunk pipeline (totaling 4,345 ft.)	$3,345

---

[15] Work cited in footnote 12.

Digitized by Google Original from THE OHIO STATE UNIVERSITY